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Comparative chemical composition of two indigenous edible mushrooms from the Teso region of Uganda (*Termitomyces microcarpus* [*Eswei*] and *Termitomyces giganticus* [*Imaruk*])

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ABSTRACT

Increasingly, mushrooms are being investigated for their role as highly nutritious foods. However, few studies have been published on their nutrient profiles. Experiments were carried out to find out the chemical composition of the two most important edible mushrooms reported from the dry land Teso region (Eastern Uganda). The results were compared using a paired sample t-test. There were significant differences in some of the chemical composition of the two mushroom species. Despite the differences in the chemical composition of the two mushroom species, the overall nutritional potential of the mushrooms were quite good. Mushrooms here were shown to be good sources of proteins with 23% to 25%. They could also be good sources of minerals such as phosphorus with concentrations of 1952mg/100g to 2084mg/100g and calcium with 41mg/100g to 51mg/100g although they were low in both lipids with 3.87% to 4.49% and vitamin A with 0.004µg/100ml to 0.005 µg/100ml. Considering the overall nutritional results, mushrooms should play an important role in our daily diets.

Key words: Edible mushrooms, dry land species, proximate analysis, high proteins, low fat contents
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INTRODUCTION

Edible mushrooms provide high quality proteins that can be produced with greater biological efficiency than animal protein. Mushrooms are rich in fibres, minerals and vitamins and have low crude fat content and high proportion of polyunsaturated fatty acids [1]. Furthermore mushroom proteins contain all the essential amino acids required for man. About 50-70% dry weight are carbohydrates, 15-50% dry weight are proteins and 1-15% dry weight are fats [1] and containing vitamins and inorganic minerals [2]; [3]. Today they are potentional protein sources especially in developing countries where animal protein is scarce and expensive [4]. Mushrooms have been relished as a delicacy for centuries because of their subtle flavour [5], nice aroma and physical taste appeal [6]. They have medicinal and ritual use. In many communities, even among people of Teso region (Eastern Uganda), mushrooms are recommended for people who are suffering from malnutrition. For these reasons, efforts are being made to increase the production of mushrooms by many government agencies and the private sector. Edible mushrooms also have various health benefits such as antioxidative, antitumour and hypercholesteroleic effects [7]. Therefore edible mushrooms are regarded as an ideal health food. The objective was to investigate the chemical composition of the two most important mushroom species among the Teso people of Eastern Uganda in order to evaluate and compare their nutritional potential.

MATERIALS AND METHODS

Mushroom handling procedures

Fresh mushroom were obtained from four microhabitat sites (cultivated area, overgrazed area, less grazed area and woodland). These were combined during sun-drying and treated as one sample. Collected samples were sun-dried for two to four days as a means of preservation. The sun-dried mushrooms were stored in a cool, dry and air tight container to avoid growth of other fungi during the analyses. Sun-dried mushrooms were weighed in a crucible in quadruplicate, dried to constant weight in an oven at 35-40^{0}C for 24hours and then cooled in desiccators and weighed again prior to grinding. The mushrooms were ground in a laboratory hammer mill to pass through a sieve of 1.5mm to increase surface area during analyses.

Proximate analyses

Proximate analysis for dry matter content, crude protein, crude fiber, crude fat, ash content, pure carbohydrates, minerals (potassium, calcium, phosphorus) and vitamins (carotene, ascorbic acid) was performed in accordance with the official methods of analysis of the Association of Official Analytical Chemists [8]. Each analysis for a chemical constituent was replicated four times. Percentage of total crude carbohydrates (by difference) was determined by subtracting moisture content, crude protein, crude fat and ash from one hundred. All the calculations were done on dry weight basis of the mushrooms.

RESULTS

From table 1, sun-dried mushrooms contain about 10% moisture content with a slight difference ($t = 3.10$; $p = 0.199$) between the two mushroom species. Specifically, *Termitomyces giganticus (Imaruk)* had higher moisture content (11.08%) compared to *Termitomyces microcarpus* (*Eswei*) (8.23%) and therefore had lower dry matter content (88.92%) as compared to 91.77% dry matter content of *Termitomyces microcarpus (Eswei)* at ($t = -3.10$; $p = 0.199$).

The table also shows that there is a significant difference ($t = -8.76$; $p = 0.003$) between the ash contents of the different mushroom species. Specifically *Termitomyces giganticus (Imaruk)* had lower ash content (9.87%) compared to 19.7% for *Termitomyces microcarpus (Eswei)*. These differences also show differences in mineral contents of the different species with *Termitomyces microcarpus (Eswei)* expected to be better sources of minerals since it has higher ash content.

The table also shows that mushrooms can be better sources of proteins since both species had percentage protein above 20%. From the study, it was shown that all the nitrogen (toatal nitrogen) released during distillation was 4.46% for either *Termitomyces giganticus (Imaruk)* or *Termitomyces microcarpus (Eswei)* with no significant difference ($t = 0.02$; $p = 0.986$). However, other nitrogen was coming from the cell walls (non protein nitrogen) and thus was determined (0.59% and 0.66% respectively) still with no significant difference ($t = -1.73$; $p = 0.182$). The protein nitrogen was calculated by the differnce between the total nitrogen and non-protein nitrogen and hence used to ascertain percentage crude protein. These were quite similar ($t= 0.31$; $p = 0.779$) with *Termitomyces giganticus (Imaruk)* edging out *Termitomyces microcarpus (Eswei)* with 24.23% compared to 23.72%. Mushrooms can therefore be good sources of protein.

The table also clearly shows that there is a significant difference in the levels of crude fibres (t = 16.97; p =0.000). Some species are hard with high cellulose content while others are soft with low cellulose contents. *Termitomyces giganticus (Imaruk)* in this case has high crude fibre content of 6.59% compared to 1.94% for *Termitomyces microcarpus (Eswei)*.

Mushrooms have low lipid contents as shown in table 1. There is a slight difference in the levels of crude lipids reaching about 4% (t=-3.8; p=0.032). Speciffically *Termitomyces giganticus (Imaruk)* had lower crude lipid of 3.87% compared to 4.49% for *Termitomyces microcarpus*. The carbohydrates (by difference) show higher percentage of 44% in *Termitomyces giganticus (Imaruk)* compared to 41.9% in *Termitomyces microcarpus (Eswei)*. However the table shows that the mushroom species contain slightly different amounts of pure carbohydrate (t = -12.15; p = 0.052) specifically 0.5315g/l in *Termitomyces microcarpus (Eswei)* compared to 0.2885g/l *Termitomyces giganticus (Imaruk)*.

Mushrooms can provide minerals too. Form table 2, it is shown that mushrooms do have essential minerals as shown by the presence of phosphorus, potassium and calcium. These minerals are present although they are found in small quantities. There was no significant difference in phosphorus (t = -1.639; p= 0.145) with *Termitomyces microcarpus (Eswei)* having mean concentrations of 2084mg/100g of phosphorus compared to *Termitomyces giganticus (Imaruk)* 1952mg/100g. Mean while there is a significant difference in calcium levels (t = 15.737; p = 0.000) with *Termitomyces giganticus (Imaruk)* having mean concentrations of 51mg/100g of calcium compared to 41mg/100g in *Termitomyces microcarpus* (Eswei). The two species however exhibited similar concentrations of potassium of 6.67mg/100g.

Table 1 Proximate composition (N=4)

	Imaruk (*Termitomyces giganticus*)		Eswei (*Termitomyces microcarpus*)		*Paired Differences*		
Varible	Mean± SEM	SD	Mean± SEM	SD	Mean± SEM	SD	P-Value
% Moisture	11.08±1.76	2.490	8.23± 2.68	3.790	2.85± 0.920	1.301	0.199
% Dry matter	88.92 ±1.76	2.490	91.77± 2.68	3.790	-2.85± 0.920	1.301	0.199
% Ash content	9.87± 0.423	0.850	19.72±1.088	2.177	-9.85±1.329	2.250	0.003
%Total Nitrogen	4.463± 0.138	0.277	4.46 ±0.091	0.183	0.003±0.128	0.255	0.986
% NPN	0.595± 0.105	0.210	0.665± 0.067	0.134	-0.07±0.040	0.081	0.182
% PN	3.878±0.226	0.451	3.795±0.0591	0.118	0.083±0.268	0.536	0.779
% Crude Protein	24.23±1.410	2.820	23.72±0.369	0.735	0.516±1.68	3.350	0.779
%Crude Fibre	6.59± 0.281	0.563	1.935± 0.026	0.052	4.66± 0.274	0.549	0.000
%Crude Lipids	3.868± 0.102	0.203	4.491± 0.062	0.124	-0.623±0.16	0.328	0.032
T. Carbohydrates	0.2885±0.024	0.033	0.5315±0.044	0.062	0.243±0.02	0.028	0.052
% D.Carbohydrates	44	-	41.9	-	-	-	-

NPN=Non Protein Nitrogen, PN=Protein Nitrogen, T=Total Carbohydrate in g/l, D= Crude Carbohydrates by Difference in %, SEM Standard Error of Mean, SD Standard Deviation. Confidence Interval = 95%.

Table 2 Mineral Contents (N=4)

Varible	Imaruk (*Termitomyces giganticus*) Mean± SEM	SD	Eswei (*Termitomyces microcapus*) Mean± SEM	SD	*Paired Differences* Mean± SEM	SD	P-Value
Phosphorus	1952±21.131	59.767	2084±59.332	167.817	-131.62±80.3	227.1	0.145
Calcium	51±0.491	1.388	41±0.8224	2.326	9.37±0.595	1.685	0.000
Potassium	6.67±00	00	6.67±00	00	-	-	-

Table 3 Vitamin C (Ascorbic acid) and Vitamin A (Carotene) (N=4)

Varible	*Imaruk (Termitomyces giganticus)* Mean± SEM	SD	*Eswei (Termitomyces microcapus)* Mean± SEM	SD	*Paired Differences* Mean± SEM	SD	P-Value
Vitamin C	0±00	0	0±00	0	-	-	-
Vitamin A	0.005±0.00005	0.0001	0.004±0.0002	0.0005	0.0005±0.0003	0.0005	0.17

Mean concentration of Vitamin C in mg/100ml and Vitamin A in µg/100ml, SEM = Standard Error of Mean, SD = Standard Deviation, Slpoe = 4.2

Table 3 above shows the concentration of vitamin C and A in sun-dried mushrooms. Since vitamins degenerate under direct sun-light, both *Termitomyces giganticus (Imaruk)* and *Termitomyces microcarpus* (*Eswei*) exhibited zero concentrations of vitamin C and surprisingly about 0.005 µg/100ml in *Termitomyces giganticus* (*Imaruk*) and about 0.004 µg/100ml in *Termitomyces microcarpus (Eswei)* with slight difference between the two ($t = 1.8$; $p = 0.17$).

DISCUSSION

The chemical constituents of edible mushrooms are not necessarily good indicators of nutritional value due their inherent characteristics such as intrinsic physiological and biochemical characteristics, genetic nature of a given strain and typical heterotrophic metabolism which would result in differences in compositional data [9]; [10]. The use of different techniques for analyses also limits a comparison of results from different studies [11]. Estimates of usable proteins for example should exclude chitin present in mushroom cell wall [9]; [12]. This is not always observed in studies. This study tried to eliminate this error by also ascertaining the non-protein nitrogen in the two mushroom species.

The study showed that *Termitomyces giganticus* (*Imaruk*) had a lower dry matter content of 88.92g compared to 91.77g for the *Termitomyces microcarpus* (*Eswei*) in 100g content. This therefore showed that *Termitomyces giganticus* (*Imaruk)* had a higher moisture content of 11.08g compared to 8.23g of *Termitomyces microcarpus* (*Eswei*). This is an indication that at temperatures of 40^0C and above, *Termitomyces microcarpus* (*Eswei*) would lose moisture faster than *Termitomyces giganticus* (*Imaruk)*. This could be due to their less fibrous nature as compared to the more fibrous nature of *Termitomyces giganticus* (*Imaruk*), which would help retain some moisture in their tissues even at such higher temperatures. The study also indicated that *Termitomyces giganticus* (*Imaruk*) had lower ash content than *Termitomyces microcarpus* (*Eswei*). The ash content could be an indicator of the mineral quantities in the different species. This would therefore mean that *Termitomyces microcarpus* (*Eswei*) presents better sources of mineral as compared to *Termitomyces giganticus* (*Imaruk*). This difference could be as a result of the differences in the ability to utilize nutrients in a given substrate and what effects, if any, the substrate would have on compositional data [11].

The study showed that the two mushroom species had similar crude protein content. Ascertaining the difference between total nitrogen content and non-protein nitrogen content for protein nitrogen values reduced the error brought as a result of values from chitin. All the species had substantially higher amounts of protein. Other studies confirm that wild edible mushrooms are nutritious and a suitable alternative for well-known foodstuffs [9]. They compare favourably using standard measures such as amino acid score, essential amino acid index, biological value and nutritional index that assess the nutritional value of food [9]. This allows for comparisons to be made between foods with small amounts of high quality proteins and those that have large amounts of lower nutritional values. The contribution to diet will depend on the amounts eaten by people, the species involved and the frequency of consumption [9]. Wild mushrooms are excellent for malnourished children [13]. They contain proteins, which are easily absorbed by the body tissues and used to boost the immunity. This could also be the reason why children suffering from measles are traditionally treated with boiled mushrooms.

The study indicated that *Termitomyces giganticus* (*Imaruk)* had high crude fibre content compared to that of *Termitomyces microcarpus*. The higher the crude fibre contents the lower the digestibility. This would mean that the body could more easily digest *Termitomyces microcarpus* (*Eswei*) and subsequently its nutrients made available for assimilation than could be got from *Termitomyces giganticus* (*Imaruk*). The differences in the fibre content could be as a result of the differences in the cellulose contents in different species although chitin and ß-glucans are the main types of fibre in fungi [14]. *Termitomyces giganticus (Imaruk)* therefore could be having higher cellulose content than *Termitomyces microcarpus*. Subsequently *Termitomyces microcarpus* (*Eswei*) would be easily subject to rot than the *Termitomyces giganticus (Imaruk)*, which would be protected by the high cellulose content. The study also showed that edible wild mushrooms were generally low in crude lipids, although the main classes of lipid compounds could be represented including phospholipids, sterols, sterol esters, monoglycerides, diglycerides and triglycerides, as well as free fatty acids [14]. Although they are not energy providing foods, they are substantially better source of nutrition than is often assumed. The low lipid content could offer very good options for people who would otherwise require low cholesterols and would avoid animal protein that could be potential sources of cholesterols.

The results of the study also indicated that mushrooms had low total pure carbohydrates. *Termitomyces microcarpus* (*Eswei*) nevertheless almost doubled the amount in *Termitomyces giganticus (Imaruk)*. This therefore could be an indicator that *Termitomyces microcarpus* (*Eswei*) is better energy food than the *Termitomyces giganticus* (*Imaruk*), the same trend shown in crude lipids. It should be noted that there was high percentages of crude carbohydrates in both mushrooms.

The study also showed that wild edible mushrooms are useful sources of minerals. The quantities could vary according to the growth substrates [12]; [15]. Mushrooms could provide a useful source of phosphorus, potassium and calcium as indicated by the study although in smaller quantities. Even within the same species, there could be variations in the quantities of the minerals since differences could be as a result of the variations in the ability to utilize nutrients in a given substrate and what effects, the substrate could have on nutrient compositions [11]. It could be therefore that *Termitomyces microcarpus* (*Eswei*) better utilized the minerals in their growth substrates and subsequently presented higher ash content and hence better mineral source than *Termitomyces giganticus (Imaruk)*.

The micronutrients in mushrooms could help to relieve disorders, which range from constipation to heart disease and cancer. For example potassium in mushrooms regularizes the heartbeat and improves oxygen supply to the brain [13]. This relieves stress. Calcium could be used by the body to build strong bones, and could play an important role in the proper functioning of the nervous system. In the body, calcium and phosphorus are at a balance. Too much phosphorus in the body could lower the amount of calcium and could lead to loss of calcium from the skeleton. Most of the nutrients in mushroom cannot be destroyed by sunlight and therefore dried ones still serve the purpose.

Mushrooms are a good source of vitamins [16] however most of them are deficient in vitamin C and A [15]. In the two species studied, none had vitamin C in agreement with earlier reports [15]. This could be because vitamins are very unstable in sun-light or heat and therefore they could have been destroyed. Surprisingly, there were traces of vitamins A in both mushrooms.

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